A MODIFICATION TO INCREASE THE VERSATILITY AND SAFETY OF THE MANLEY VENTILATOR*

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THIS PAPER DESCRIBES a modification to a commonly used ventilator. This modification increases the maximum inflation pressure which the ventilator will deliver, eliminates the safety valve presently fitted (which tends to malfunction) and replaces it with an adjustable and more reliable safety valve.

A clinical trial has proved the reliability and effectiveness of these modifications.

The Manley ventilator,[1] although originally intended for use in the Operating Room (Figure 1) is finding increasing use in Intensive Care Units.[2]

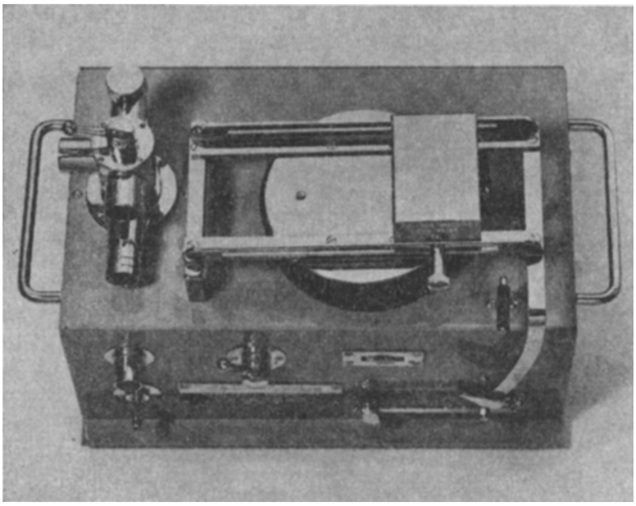

FIGURE 1. Standard Manley MN2 Ventilator.

The basic concept of using a "Minute Volume Divider" employing a low driving pressure (100–150 cms H_2O) leads to constancy of ventilation and easily varied inspired oxygen concentrations. (The Manley can be run off 2 flowmeters, one oxygen and one air, running into one tube and on into the ventilator.)

The Manley ventilator has, however, the following major drawbacks. Firstly, the safety valve (set at 35 cms H_2O) has a tendency to corrode and become stuck down and then does not open at the required pressure. Secondly, the maximum

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Canad. Anaesth. Soc. J., vol. 18, no. 6, November 1971

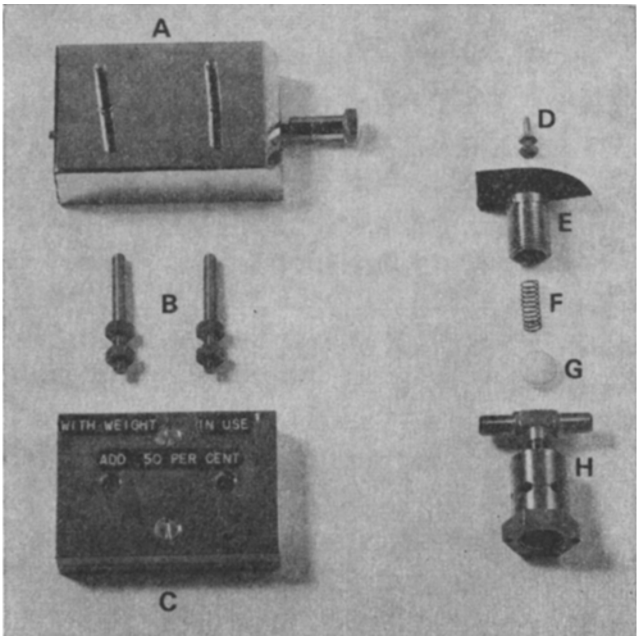

FIGURE 2. Parts needed to modify the ventilator showing:
A. Locating pins fitted onto existing bellows weight
B. Locating pins to locate weight when not in use
C. Extra weight
D. Stop pin to limit movement of safety valve adjustment
E. Safety valve screw
F. Spring
G. Safety valve disc
H. Safety valve body.

pressure is limited to 35 cms H_2O by the size of the weight on the bellows. In an attempt to improve this situation, we modified this ventilator by increasing the weight used to drive the gas into the patient during inspiration and by fitting an adjustable safety valve which will not stick (Figure 2). The result was to increase the maximum pressure deliverable to the patient to 52.5 cms H_2O with a functioning safety valve.

METHOD

The weight on the bellows was drilled and tapped to take 2¼ in. × 2 in. pins of stainless steel as locating pins (see Figures 2 and 3).

A brass weight was then made to conform in perimeter to that present on the ventilator. Two holes were drilled through this weight into which the two locating pins would fit, and it could henceforth be held on the top of the present weight. A further two locating pins of the same dimensions and spacing were fitted behind the bellows on the top of the ventilator body to locate the weight when not in use.

This weight was enough to increase the inflation pressure to 52.5 cms H_2O as a maximum.

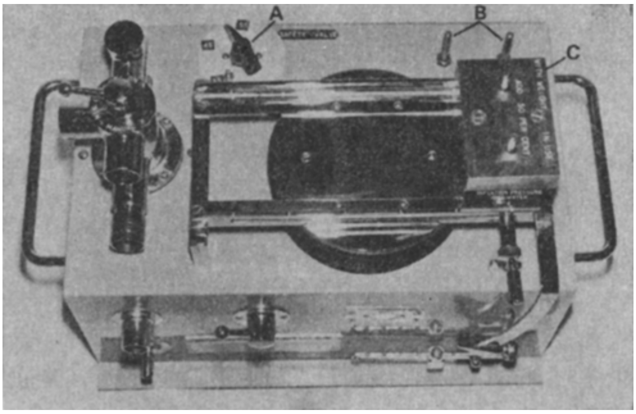

FIGURE 3. Manley MN2 Ventilator with modification (see figure 2) fitted. Showing:
A. Safety valve adjustment
B. Locating pins for weight when not in use
C. Extra weight in position located on existing bellows weight by two pins.

The next thing needed was to improve the function of the safety valve, and increase its blow off pressure.

The standard safety valve was tightly screwed down so that it could not open. A new valve with a variable blow off from 35 to 55 cms H_2O, was fitted into the top of the ventilator casing.

The new safety valve was connected in between the manual automatic control (Figure 4, #28) and the old safety valve (Figure 4, #11).

SPECIFICATIONS

New Weight:

Weight: 900 grams
Size: 3⅝″ × 2½″ × ¾″
Material: Brass

Safety Valve:

Material: Brass
ID 3/4, OD 15/16, No. of holes: 6, Size: 3/16 in.
Thread: 2 start, 8 threads/inch
Spring: Stainless steel, .021 in. thick, ⅞ in. long, .320 in. diameter
Size of seat: ½ in. diameter
Valve disc: ⅝ in. diameter, Material: Delryn (Du Pont)

Having fitted these modifications, further alterations became necessary to make the ventilator function perfectly. It was found that during expiration the bellows would not refill fully with gas, and so the ventilator would not recycle properly. It became necessary therefore to increase the spring tension of the spring marked

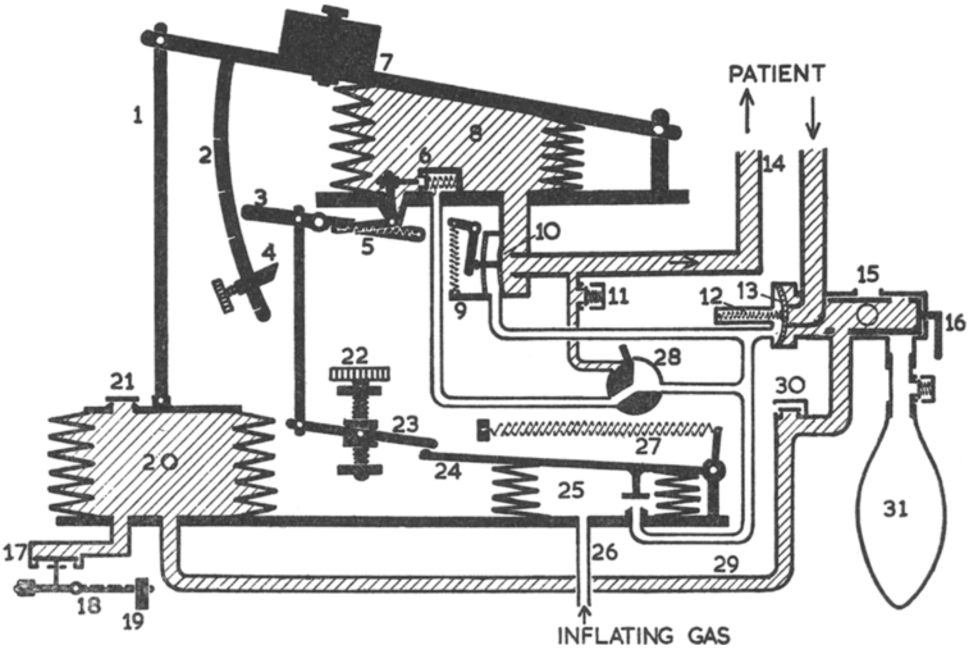

FIGURE 4. Diagram of the Manley Ventilator reproduced from page 614 of Automatic Ventilation of the Lungs, 2nd Edition, by kind permission of the author and publishers.

1. Connecting rod
2. Arm
3. Lever of click mechanism
4. Adjustable stop, limiting tidal volume
5. Click mechanism
6. Inlet valve of main concertina bag
7. Top plate of main concertina bag with movable weight
8. Main concertina reservoir bag
9. Expansion spring of inspiratory valve
10. Inspiratory valve
11. Safety valve
12. Expansion spring of safety valve
13. Diaphragm of expiratory valve
14. Inspiratory tube
15. Port
16. 3-position tap
17. Inlet valve
18. Arm
19. Counterweight
20. Negative-pressure concertina bag
21 One way valve
22. Inspiratory phase control
23. Lever of click mechanism
24. Top plate of small concertina bag
25. Small concertina bag
26. Inflating-gas inlet
27. Expansion spring
28. Manual/automatic control
29. Connetcing tube
30. One-way valve
31. Reservoir bag for manual inflation.

9 in Figure 4. This is easily done inside the machine by altering the position of the lock nuts on the threaded shaft holding the end of the spring.

The reason for this is as follows:

During the expiratory flow the valve (6) operated by the click mechanism (5) is open and gas flows from the small concertina bag (25) into the reservoir bag (8). The concertina bag (8) expands lifting the top plate with its movable weight (7) and with it the arm (2), until the adjustable stop (4) strikes the arm (3) reversing the click mechanism (5). This allows the valve (6) to be closed by its spring. Now that the flow of gas from the concertina bag (25) to the bag (8) is stopped, the pressure in the circuit rises towards that in the bag (25). The pressure rise also

occurs behind the diaphragm (13) of the expiratory valve and behind the diaphragm of the inspiratory valve (10). When the pressure has risen sufficiently, the pull of the spring (12) on the diaphragm (13) is overcome, the diaphragm (13) now opens closing the expiratory valve. As the pressure continues to rise, the force of the larger diaphragm of the inspiratory valve (10) becomes sufficient to overcome both the force on the smaller diaphragm and the pull on the spring (9). This opens the inspiratory valve and allows the weight (7) to force the content of the bag through the inspiratory tube (14) to the patient.

This is the normal functioning of the ventilator during expiration. If, however, the pressure needed to fill the bellows (8) is higher than before due to extra weight added onto weight (7) then the pressure being exerted on the larger diaphragm of valve (8) against the action of the spring (9) increases.

The smaller diaphragm will therefore tend to lift slightly from its seat, so connecting the patient to the gas in the bellows. At this point however, the diaphragm (13) will not have sufficient pressure behind it to keep it closed so that gas will slowly leak out to the atmosphere through valve (13).

It was found that the bellows would lift up to approximately three-quarters of its travel but that when the added effort of moving lever (3) with lever (4) was needed, sufficient extra pressure developed in the bellows to cause the gas to leak from the machine.

It will be seen, that when the pull of spring (9) is increased, a higher pressure will be needed between the two diaphragms to lift the smaller diaphragm (10) off its seat. Thus a sufficient increase in tension compensates for the effect of the added pressure in the concertina bag (8).

However, the after effects on the valve system of the increased pressures and spring tension must also be considered.

With the increased spring tension (9), it was anticipated that the valve (10) would open slightly less during inspiration, and that valve (3) would open less during expiration, due to increased pressure behind the diaphragm (13) during expiration. The resistance to expiration might then be increased. Experimentally, the inspiratory resistance between the bellows and the patient and the expiratory

Name	Age	Sex	Tital vol. in ccs	Min. vol. in Litres	Inspired O_2 %	Inspiratory pressure used cms H_2O	PaO_2 mmHg	$PaCO_2$ mmHg	pH	Bicarbonate	Result	
M.V.	52	♂	800	14	88	50 EPP +5	144	63	7.41	38.8	Alive	Oesophago bronchial fistula
A.H.	66	♂	800	12	66	45	83	48	7.36	26.2	Alive	Chronic bronchitis Severe C.C.F.
T.B.	28	♂	700	12	73	42	149	38	7.38	21.8	Dead	Multiple tauma Pseudomonas Pneumonia
E.B.	67	♂	800	10	92	37.5	102	42	7.47	30.1	Dead	Cardiogenic shock
M.P.	31	♀	800	14	100	52	111	40	7.49	30.4	Alive	Post closure of A S D With secondary pulmonary oedema
M.B.	58	♀	700	14	94	52	69	42	7.49	31	Dead	Perforated bowel Broncho pneumonia Congestive cardiac failure

FIGURE 5. Blood gas/ventilation data from 6 patients on which the modified Manley Ventilator was used.

resistance of the ventilator did not change from the original, provided that the spring tension was increased only enough just to stop leakage with an extra 400 grams added to the extra weight, with the ventilator set at maximum inflation pressure.

This modified unit was given a clinical trial. It was reserved for patients requiring high inflation pressures (because of bronchospasm, pulmonary oedema, pneumonia, etc) and accurate control of oxygen concentrations. The results have been tabulated (Figure 5) in 6 patients in whom ventilation with a Bird Mk 7 ventilator was found to be inadequate. In all cases there was difficulty in increasing the Po_2 and improvement in ventilation and gas exchange occurred after these patients were placed on the modified Manley ventilator.

Conclusion

It has been found that by carrying out simple modifications to the Manley ventilator, consisting of an extra weight and an adjustable safety valve an improvement in the versatility and safety of the ventilator is accomplished.

Acknowledgement

We would like to thank Lt Commander Thompson for his great help in the engineering of these modifications, and Dr Dwight I. Peretz (Director of the Medical Intensive Care and Coronary Care Units, St Paul's Hospital, Vancouver) for allowing us the opportunity to carry out a clinical trial of this modified ventilator on patients under his care.

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